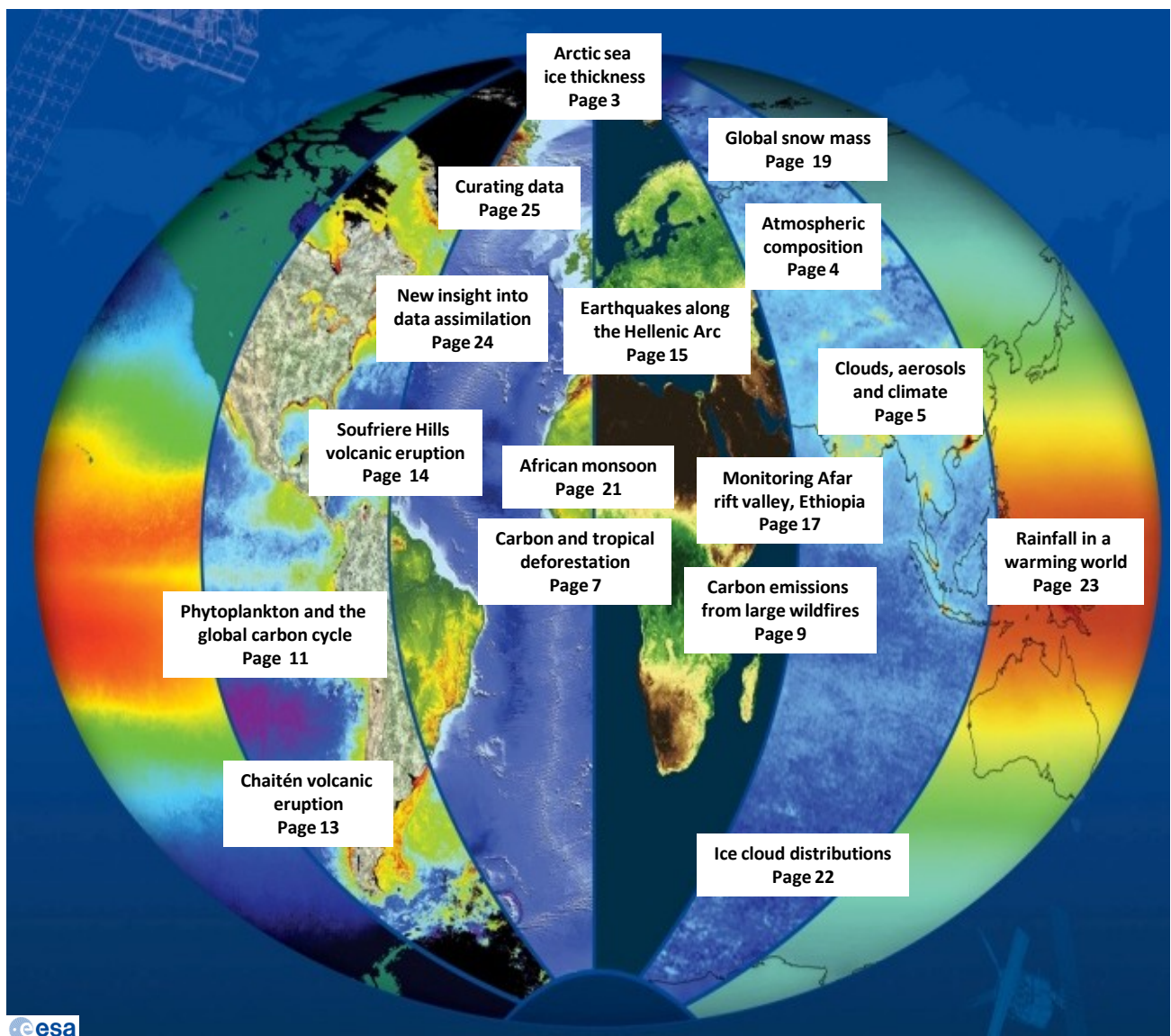




www.nceo.ac.uk

A circular collage of 12 images representing various space and Earth science topics. The images include: a sunset over a city, a satellite view of Earth's clouds, a satellite view of a forest, a satellite view of a city, a satellite view of a coastline, a satellite view of a city, a satellite view of a coastline, a satellite view of a city, a satellite view of a coastline, a satellite view of a city, a satellite view of a coastline, and a satellite view of a city.

NCEO: Exposing how the Earth system works



A selection of science stories 2008/09



The National Centre for Earth Observation is one of the NERC's research and collaborative centres. Our core concern is fundamental science: the challenge of understanding planet Earth as a complex, multi-component, coupled system. Our core competence is the ability to utilise the wealth of observations from Earth-orbiting satellites to record how the Earth is changing, to understand why it is changing and to pinpoint errors in the mathematical models that are used for prediction.

The NCEO has now been running for just over a year (from April 2008). This brochure is a selection of our early scientific achievements, exemplifying our multi-disciplinary scope. They are presented as short, scientific "detective stories", which give important clues that we piece together to figure out how the Earth system works as a whole. The extremely important role of satellite data is clearly demonstrated. The stories show our exploitation of a wide range of European satellite systems such as the European Space Agency's ENVISAT satellite and also our reliance on US systems such as NASA's Cloudsat/Calypso. I believe the work summarised in this brochure represents a major contribution to the NERC's strategic scientific objectives.

If you would like to know more about these stories or about our work and plans in the NCEO, please let me know.

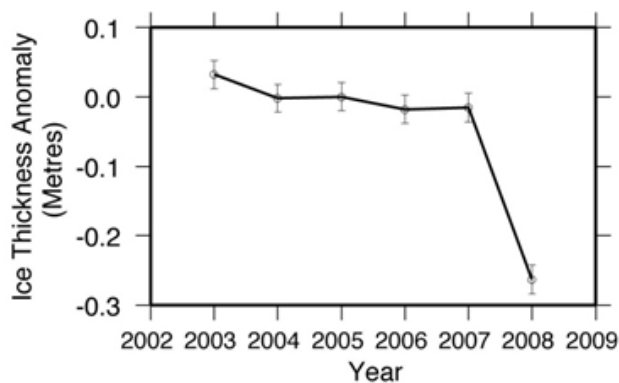
Alan O'Neill
Director, National Centre for Earth Observation

Trends in Arctic sea ice thickness

Katharine Giles, Seymour Laxon, Andrew Ridout, UCL

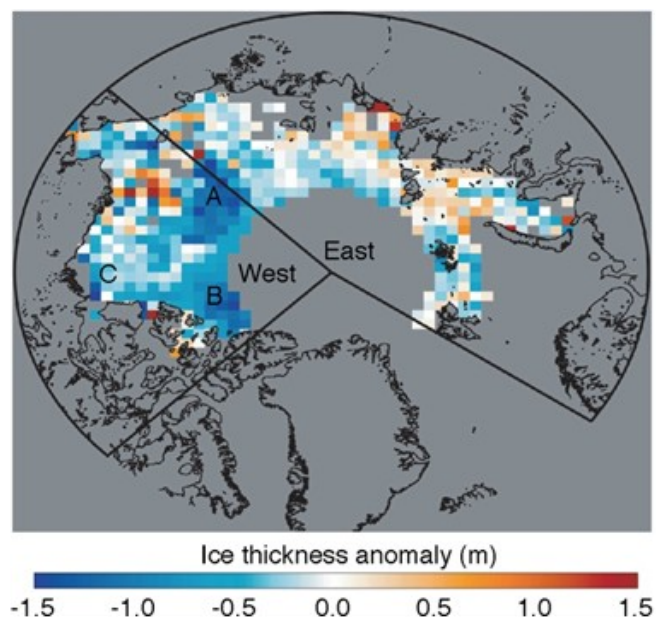
In the September 2007 the extent of Arctic sea ice reached a record minimum of 4.1 million km², a level that previously climate models predicted would not occur until at least 2040. A number of different explanations for the cause of the 2007 minimum have been suggested including unusual weather conditions in the summer of 2007 resulting in enhanced ice melt over that summer, combined with long-term pre-conditioning through ice thinning. A key parameter in understanding the mechanisms responsible for the record ice minimum is how the ice thickness changed over this period.

Using data from the radar altimeter onboard the European Space Agency's Envisat satellite we generated the first time-series of Arctic winter (Oct-Mar) sea ice thickness for the period 2002-2008. The results show a significantly thinner ice cover in the winter that followed the 2007 minimum and no evidence for short-term pre-conditioning prior to the 2007. These results support the hypothesis that unusual weather conditions in the summer of 2007 played a significant role in causing the September ice minimum. They also show however that the ice extent minimum probably led to much thinner ice in the following winter, a likely reason why only a small recovery in September ice extent occurred in 2008.



Ice thickness changes in the years preceding the 2007 minimum and in the following winter.

Ice thickness during the winter 2007/8 compared with the 2002-2008 average. The results show strong regional variability in changes with ice more than one metre thinner than the average in some areas.



References

Giles, K. A., S. W. Laxon, and A. L. Ridout (2008), *Circumpolar thinning of Arctic sea ice following the 2007 record ice extent minimum*, Geophys. Res. Lett., 35, L22502, doi:10.1029/2008GL035710.

New mission to understanding processes controlling atmospheric composition

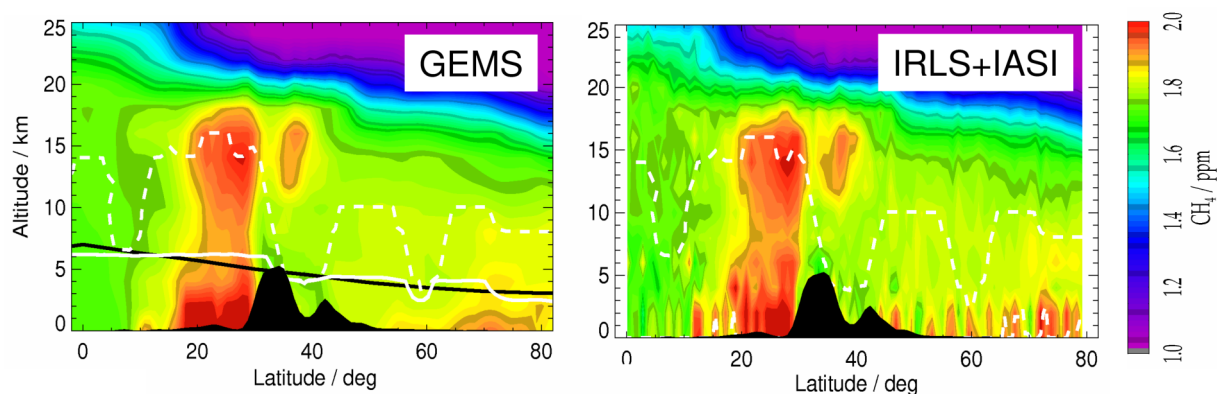
Brian Kerridge, Rutherford Appleton Laboratory

Climate is particularly sensitive to atmospheric composition in the mid- to upper troposphere and lower stratosphere (5-20km height range). Global distributions in this height range are controlled by processes which occur on fine scales. The objective of the proposed PREMIER mission is to resolve 3-D distributions in this region for the first time from space on the fine scales needed to quantify links between atmospheric composition, climate and pollution.

Relationships between atmospheric composition and climate: Detailed distributions of the important climate gases, water vapour, ozone and methane will be critically examined, and representation of their forcing/feedback processes will be improved in climate models.

Atmospheric transport processes important to climate and air quality: Convective transport and other processes linking the tropical troposphere and lower stratosphere will be characterised. Individual plumes of organic and nitrogen compounds (ozone precursors) from biogenic, pyrogenic and anthropogenic sources will be resolved in 3-D for the first time. Links with surface emissions and pollution will be explored by exploiting synergies with nadir-sounders on EPS-MetOp.

Relationships between atmospheric dynamics and climate: Gravity waves, their influence on stratospheric circulation and other mesoscale dynamics will be characterised by resolving (3-D) temperature structure down to fine scales.



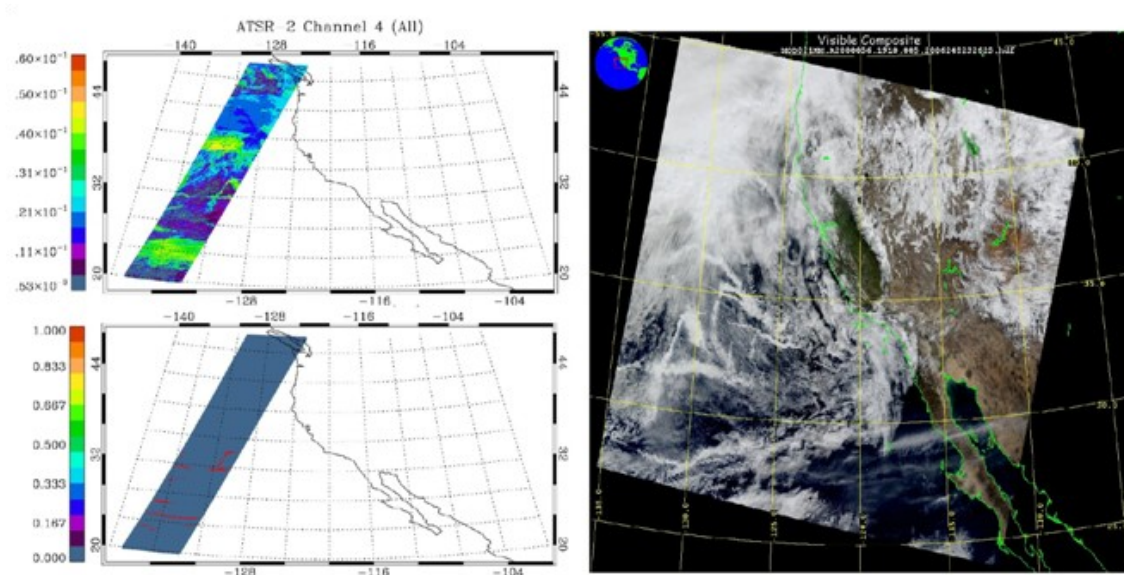
The left-hand panel shows uplift of biogenic methane emitted from Bangladesh wetlands during the 2003 monsoon, as represented by the ECMWF/GEMS system in a height/latitude cross-section. The retrieval simulation in the right-hand panel shows how the PREMIER Infrared Limb Sounder (IRLS) will capture detailed structure in the distribution above 5km and, in combination with the MetOp IR Atmospheric Sounding Interferometer (IASI), down to the source region.

Following its selection by ESA for Phase A study, PREMIER is now one of three remaining candidates for Earth Explorer 7, to be launched in 2016. Scientists in NCEO together with UK colleagues played an important role in preparing the scientific case. ESA's Mission Assessment Group included Dr. B.Kerridge (RAL, chair), Dr.P.Palmer (U.Edinburgh) and Prof. Piers Forster (U.Leeds), along with Dr. Niels Bormann (ECMWF) and scientists from Canada, Sweden and Germany. The scientific case drew heavily on retrieval simulations to illustrate novel observing capabilities of the mission, such as that shown in the figure, which were performed by an international team including NCEO scientists at RAL and U.Oxford.

New insight into clouds, aerosols and climate

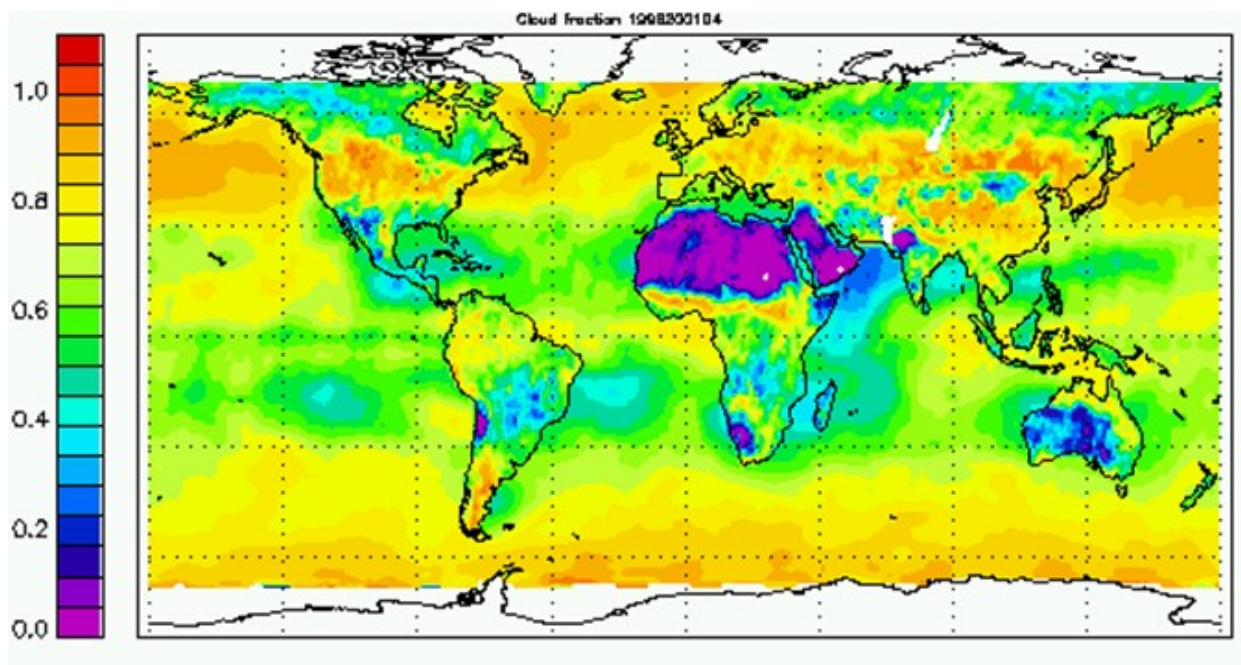
Don Grainger , Andy Sayer, Chris Arnold, Gareth Thomas,
Elisa Carboni, University of Oxford
Caroline Poulsen, Richard Siddans Barry Latter,
Bryan Lawrence, Rutherford Appleton Laboratory

Clouds have long been recognised as one of the key moderators of the Earth's atmosphere. Low clouds such as stratus effectively reflect incoming solar radiation giving an overall cooling effect while high clouds such as thin cirrus can transmit solar radiation but trap the outgoing thermal radiation to give an overall warming effect. Furthermore the complex response of clouds to climate change in the presence of aerosol (man-made or natural) is not well understood. The feed-back processes whereby small changes in cloud coverage and properties could alter the atmospheric circulation have been identified by the Intergovernmental Panel on Climate Change (IPCC) as key area of uncertainty. Scientists at the University of Oxford and Rutherford Appleton Laboratory have developed a state of the art cloud and aerosol retrieval algorithm and applied it to ATSR-2 data from 1995 to 2001. Processing of data from 2002- the present day is currently underway. The data set provides information on cloud optical depth, cloud phase, cloud particle effective radius, cloud top pressure, cloud fraction and cloud water path. Aerosol optical depth and particle effective radius are provided over the oceans. The production and scientific analysis of this data set are already helping our understanding of the role aerosols and clouds play in climate. The data set has been used to investigate the aerosol indirect effect (Bulgin et al., 2008) and to detect modified cloud arising from ship tracks globally (Campmany et al., 2009). To date the detection algorithm has been applied to 1999 and 2000 but ongoing work will extent this through the whole (A)ATSR mission.



The figure above shows an example scene with ship tracks on 25 February 2000, off the coast California. Top-left: ATSR-2 Channel Channel 4. Bottom-left: Ship track mask detected. Right: MODIS image false colour.

The ORAC (Oxford, RAL Aerosol and Cloud) algorithm is an application of optimal estimation to the retrieval of atmospheric properties: all available measurements and all available a priori information are combined using fast radiative transfer and known error characteristics to find the most probable state of the atmosphere. The radiative transfer includes cloud, aerosol, atmosphere and surface effects and (currently) assumes a plane-parallel single layer cloud. A key advantage of the technique is that it provides associated error measurements and quality control monitors.



The figure shows average cloud fraction for April between 1996 and 2001. Clearly visible are the southern and northern hemisphere storm tracks and the Intertropical Convergence Zone (ITCZ) with high amounts of tropical convective cloud.

The data can be accessed on the BADC website <http://badc.nerc.ac.uk/data/grape/>

References

Thomas G.E., E. Carboni, A.M. Sayer, C.A. Poulsen, R. Siddans and R.G. Grainger, Oxford-RAL *Aerosol and Cloud (ORAC): aerosol retrievals from satellite radiometers in Satellite Aerosol Remote Sensing Over Land* (Eds: A.A. Kokhanovsky and G. de Leeuw), Springer, 2009.

Campmany E, R.G. Grainger, S.M. Dean, A.M. Sayer, *Automatic detection of ship tracks in ATSR-2 satellite imagery*, Atmos. Chem. Phys., 9(6), 1899-1905, 2009.

Bulgin C.E., P.I. Palmer, G.E. Thomas, C.P.G. Arnold, E. Campmany, E. Carboni, R.G. Grainger, C. Poulsen, R. Siddans, B.N. Lawrence, *Regional and seasonal variations of the Twomey indirect effect as observed by the ATSR-2 satellite instrument*, GRL, 35, L02811, doi:10.1029/2007GL031394, 2008.

Reducing the huge uncertainties in carbon emissions from tropical deforestation

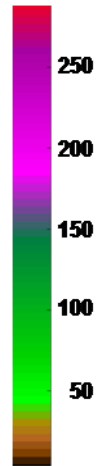
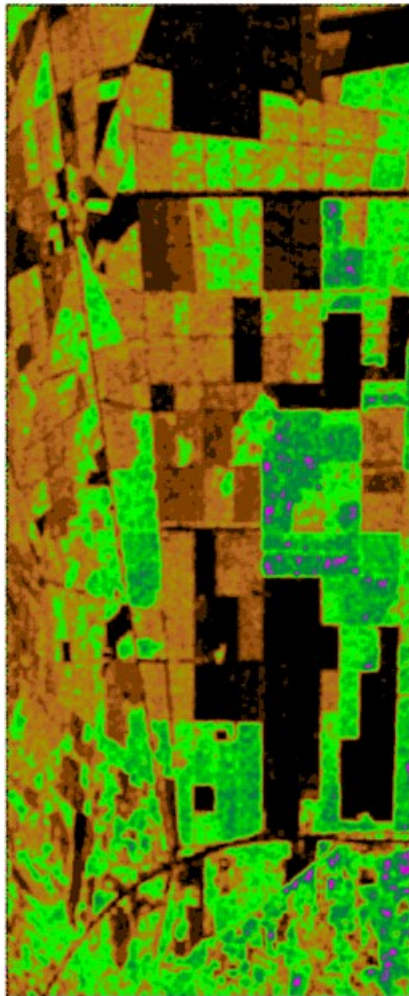
Shaun Quegan, University of Sheffield

Huge uncertainties in the carbon emissions from tropical deforestation arise from our limited knowledge about the biomass of these forests. This problem is addressed by the BIOMASS mission that has just been selected by ESA for Phase-A study. BIOMASS will be able to measure forest biomass and height, forest disturbance and regrowth at scales of 50-100 m across the globe. It meets an urgent need to understand how changes in the world's forests affect the climate and resources. It is also an ideal sensor to provide information needed by the UNFCCC, especially for the Reduction of Emissions from Deforestation and Forest Degradation mechanism that will allow tropical countries to gain carbon credits for preserving their forests.

What makes this possible is the long wavelength radar (68 cm, often referred to as P-band) to be carried by the satellite, since this gives high sensitivity to biomass. Only in late 2003 did the International Telecommunication Union make this wavelength available for Earth Observation, because of possible interference with military systems. The BIOMASS team, led by Shaun Quegan and Thuy Le Toan (CESBIO, Toulouse), responded rapidly to this new opportunity, making a proposal that was accepted for preliminary studies by ESA in 2006, along with five other missions aiming to measure different aspects of the Earth system. Only three missions survived the key selection meeting in Lisbon in February 2009 at which all six missions were presented, and BIOMASS is one of them. The next two years will be spent in critical assessment of the end-to-end science and technology of the mission, with the aim of getting BIOMASS through the final selection in 2011.

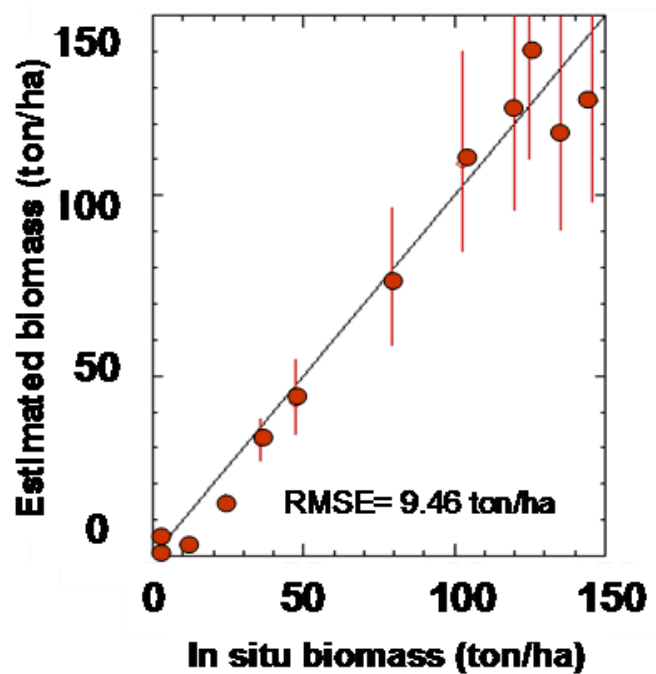
An example of the type of measurements that BIOMASS will be able to make is illustrated by the image shown in the figure, which was acquired by the NASA AirSAR airborne radar system. This is at finer spatial resolution than will be possible from space (bandwidth restrictions mean that the images from BIOMASS will have spatial resolution of around 50 m) and space data will cover a much larger area (typical images will cover 100 km by 100 km), but otherwise it is fairly representative of the capabilities expected from BIOMASS. The region shown is a part of the les Landes temperate plantation forest in southern France and the biomass has been derived from inverting the received power when a horizontally (H) polarised wave is transmitted and the vertically (V) polarised component of the return is measured. The plot on the right shows how good the comparison is between biomass derived from the radar and ground-based measurements for twelve forest stands. Many similar experiments have been performed over a range of forest types, from the tropics to the boreal zone. For the more complex and denser forests, such as tropical forests, achieving high accuracy in biomass requires use of extra polarisations combined with measurements of forest height. A major feature of the BIOMASS mission is that these height measurements will be provided using the same radar, with a technique known as polarimetric interferometry. This will allow biomass estimates to be made over the full range of biomass in the Earth's forests.

This first chance to see the Earth at P-band will also give completely new information on the subsurface structure of arid zones and ice masses, due to its ability to penetrate deep into dry soils and ice.



Map of biomass for a section of the Landes forest (about 3.5 km x 9.5 km) derived by inverting the P-band HV backscatter measured by AirSAR.

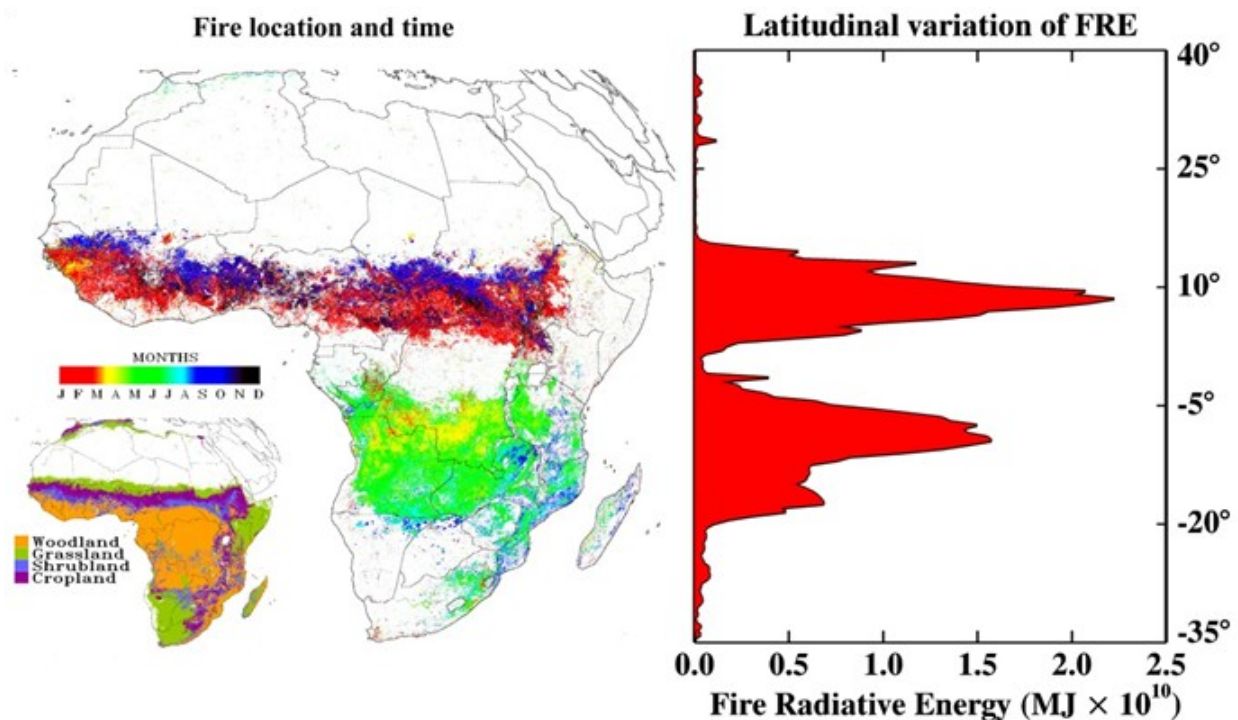
Comparisons between ground-based measurements of biomass and backscatter inversions for twelve stand (data courtesy of Thuy Le Toan, CESBIO, Toulouse).



Estimating burnt biomass and carbon emissions from large wildfires

Martin Wooster, Gareth Roberts, King's College London, working with Johannes Kaiser (ECMWF)

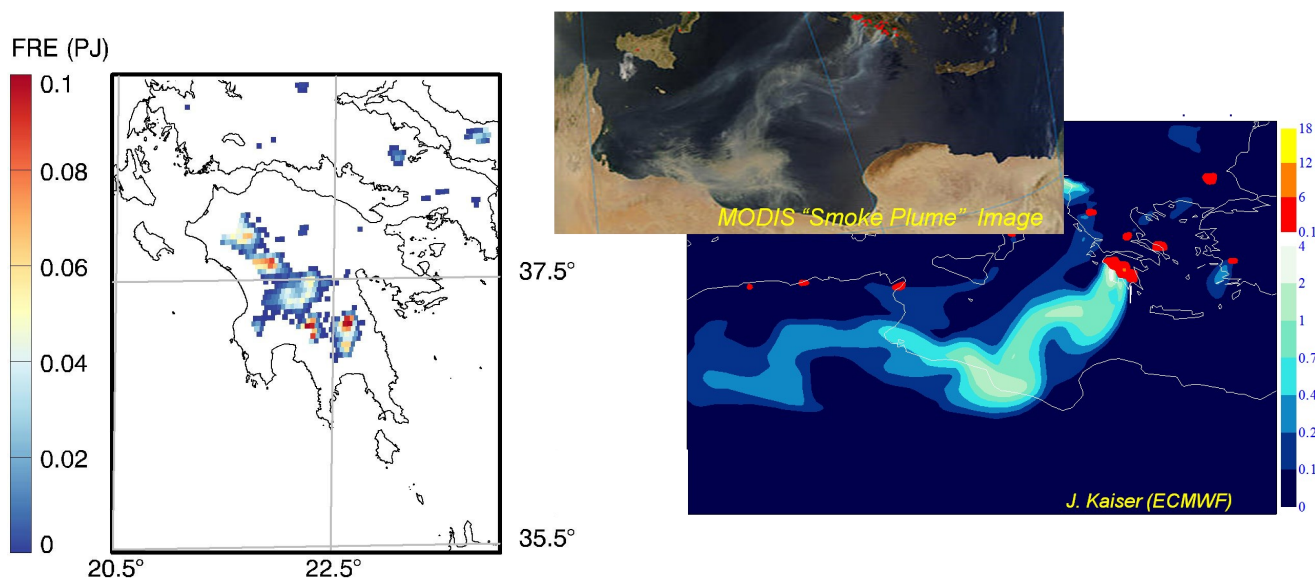
Working primarily with Meteosat SEVIRI data, we have developed a method to measure the radiative heat output from large wildfires and use it to estimate both how much biomass is being burnt and the ensuing carbon emission rate. The same technique can be used to estimate trace gas and aerosol fluxes. Since data are available every 15 minutes from the geostationary Meteosat, we can measure continental-scale carbon emissions from fires in unprecedented temporal detail. Smaller fires are sometimes missed by the geostationary data, but this bias can be corrected by using more spatially detailed but less frequent polar orbiting satellite data. The diurnal, seasonal and inter-annual patterns of continental scale fire emissions can be probed by this technique, and we have used it to gain a much more complete understanding of the dynamics of fire on the African continent, which provides the largest fraction of global fire emissions.



This figure of African biomass burning contains a map of SEVIRI active fire detections over Africa (coloured by day of detection) during one year; the six month shift between the fire seasons in the Northern and Southern hemisphere is clear. The plot on the right illustrates the latitudinal variation of Fire Radiative Energy over Africa.

These methods, first developed and tested over Africa, were recently used to study the biomass consumption and smoke emission rates in the series of huge fires occurring in late August 2007 on the Greek Peloponnese. The derived smoke aerosol emission rates were input into an adapted version of the ECMWF Integrated Forecasting System (IFS) - an extension of the operational weather model with a new aerosol module. This allowed simulation of these Mediterranean smoke plumes with unprecedented detail, giving forecast aerosol plume dispersal and aerosol optical depths that were very well matched to independent satellite and ground-based observations.

This is the first time that a full simulation of a major European forest fire pollution event has been conducted with this novel combination of geostationary satellite fire radiative power observations and atmospheric modeling and it opens the way for real-time simulation of the transport of fire smoke emissions. In future, similar techniques will be used to model the dispersal of trace gas plumes downwind of fire affected areas in other parts of the globe using observations from different geostationary satellites, enabling improved interpretations of the increased trace gas column concentrations seen in data from instruments such as MOPITT and the recently launched GOSAT.



The map of the Greek Peloponnese region (left) highlights the SEVIRI-measured Fire Radiative Energy (in Petajoules) observed over a period of intense forest fires between 23-29 August 2007. Also shown on the right is one frame of a simulation of the associated smoke plume, as modelled using the global atmospheric aerosol model developed by the GEMS (Global and regional Earth-system Monitoring using Satellite and in-situ data) project at the European Centre for Medium-Range Weather Forecasts (ECMWF). The geostationary Fire Radiative Power data from King's College London are used as the fire input, and the fuel consumption rates converted into rates of aerosol production that are then fed into the GEMS model. The remarkable agreement between the simulation and the plume actually imaged by MODIS at the same time (shown at top: <http://rapidfire.sci.gsfc.nasa.gov>) is clear. GEMS runs led by J. Kaiser of ECMWF (Kaiser et al., 2009).

References

- Wooster, M.J., Zhukov, B. and Oertel, D. 2003. *Fire radiative energy for quantitative study of biomass burning: Derivation from the BIRD experimental satellite and comparison to MODIS fire products*. Remote Sensing of Environment 86: 83-107.
- Wooster, M.J., Roberts, G., Perry, G. and Kaufman, Y.J. 2005. *Retrieval of biomass combustion rates and totals from fire radiative power observations: calibration relationships between biomass consumption and fire radiative energy release*, Journal of Geophysical Research 110, D21111: doi: 10.1029/2005JD006318.
- Freeborn, P.H., Wooster, M.J., Hao, W.M., Ryan, C.A., Nordgren, B.L. Baker, S.P. and Ichoku, C. (2008) *Relationships between energy release, fuel mass loss, and trace gas and aerosol emissions during laboratory biomass fires*, Journal of Geophysical Research, Vol. 113, No. D1, D01102, 10.1029/2007JD008489
- Roberts, G. and Wooster, M.J. (2008) *Fire detection and fire characterization over Africa using Meteosat SEVIRI*, IEEE Transactions on Geoscience and Remote Sensing, 46, 1200-1218, doi: 10.1109/TGRS.2008.915751
- Kaiser, J. W. Boucher, O., Doutriaux-Boucher, M., Flemming, yJ., Govaerts, Y. et al., Gulliver, J., Heil, A., Jones, L., Lattanzio, A., Morcrette, J-J., Perrone, M., Razingier, M., Roberts, G., Schultz, M., Simmons, A., Suttie, M., Wooster, M. (2009) *Smoke in the air*, /ECMWF Newsletter/, 119. p. 9-14.

Estimating the role of different phytoplankton groups in the global carbon cycle

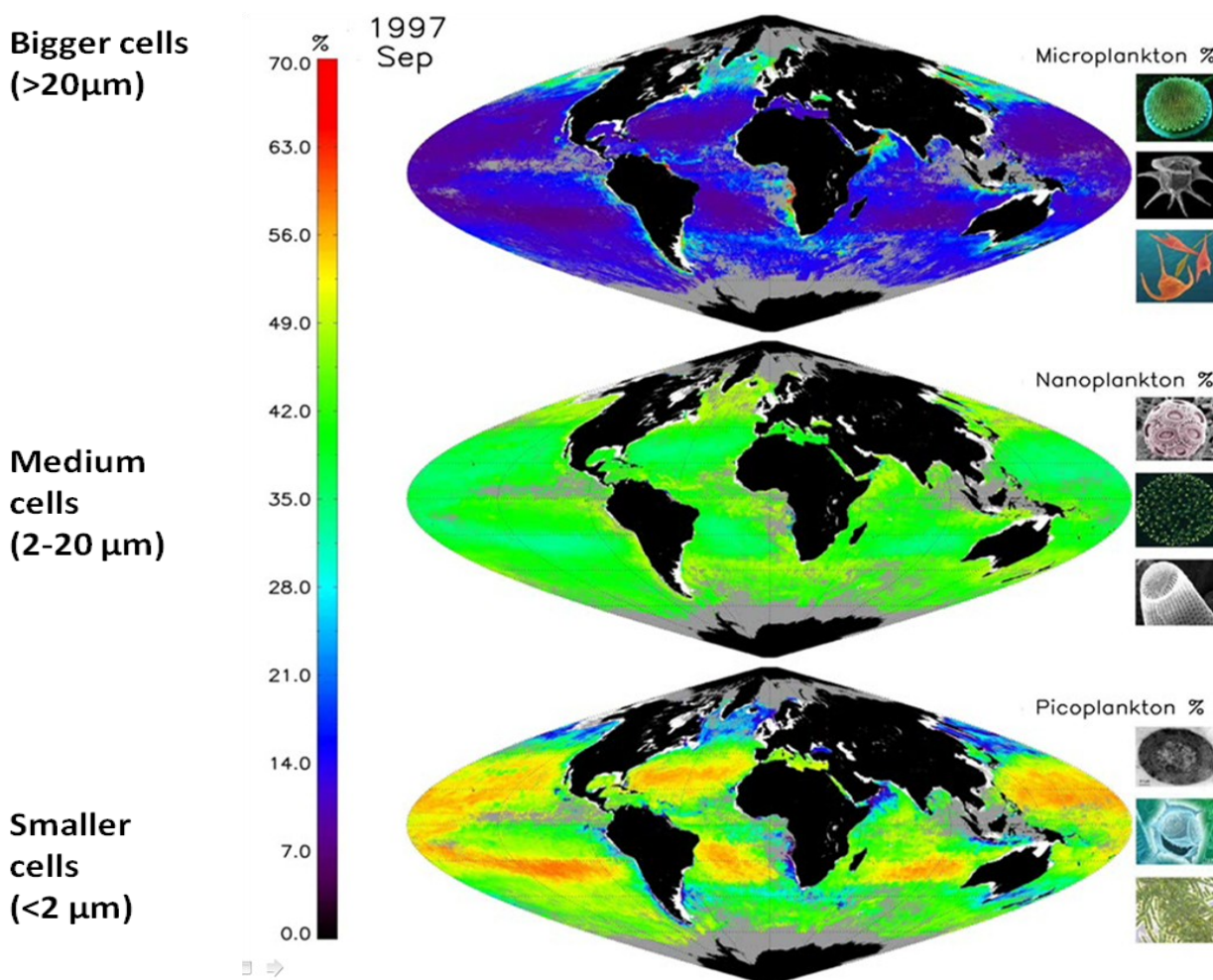
Takafumi Hirata, Bob Brewin and Nick Hardman-Mountford, Plymouth Marine Laboratory

Phytoplankton support zooplankton / fish production as a primary carbon source, and some phytoplankton species are even preferably grazed by zooplankton / fish. In addition, phytoplankton provide some biogeochemical functions which may feedback to the Earth's climate (e.g. Dimethylsulphide production by haptophytes / dinoflagellates could affect cloud / aerosol production in the atmosphere to alter the Earth's radiation budget; calcification by coccolithophores may locally increase partial pressure of CO₂ in the ocean to act as a potential source of CO₂ to the atmosphere). Primary production, zooplankton / fish grazing and the biogeochemical functions are taxonomy dependent. Therefore identifying the community structure of the phytoplankton can provide useful information for the quantification and understanding of these processes. Observing the *in situ* taxonomic groups of phytoplankton at a global scale is a challenging task. Satellite observation is probably the only practical method of observing the global ocean synoptically. With increasing concern as to how climate variation is affecting marine ecosystems, there is a large expectation on satellite remote sensing to provide global observation of the taxonomic or functional groups of phytoplankton moving beyond conventional pigment biomass (i.e. chlorophyll-*a*, hereafter denoted Chl*a*).

Table 1. Linkages between phytoplankton taxonomy, functional group and size class

Taxonomic group	Major biogeochemical function	Size class
Diatoms	C, Si	Micro (~ 20 µm)
Dinoflagellates	C, DMS	Micro (~ 20 µm)
Haptophytes	C, CaCO ₃ , DMS	Nano (2 – 20 µm)
Cyanobacteria	C, N ₂	Pico (< 2 µm)

Phytoplankton taxonomic and functional groups are closely related to Phytoplankton Size Classes, PSCs (Table 1). We have developed a satellite algorithm to derive PSCs (Hirata *et al.*, 2008). The algorithm has been validated against *in situ* measurements of phytoplankton biomarker pigments (Brewin *et al.*, 2008). The figure shows % Chl*a* of three size classes in September 1997. Microplankton is abundant mainly at mid-high latitudes and spatial distribution can be patchy. Nanoplankton are moderately abundant globally, acting as a “background population”, but relatively higher at equatorial and mid-high latitudes and relatively lower in subtropical gyres. Picoplankton mainly dominate oligotrophic gyres. The approach allows for size-specific properties to be investigated, such as primary production (Hirata *et al.*, in press). In this paper we have derived size-specific photosynthetic rates for ocean upwelling regions using satellite measurements of ocean colour, using a simple approach that links photosynthetic rate to phytoplankton size classes with the optical absorption of marine planktonic algae (phytoplankton). Comparisons with conventional methods for estimating the bulk photosynthetic rate (based on estimates of chlorophyll pigment concentration) and with *in situ* measurements showed good agreement with our approach. Preliminary results from satellite observations for upwelling regions suggest that production in nanoplankton (2–20 micron) dominated communities may be larger than for those where microplankton is predominant, due to the greater spatial extent of the former. However, photosynthetic rate per unit volume is shown to be larger for microplankton (>20 micron) dominated communities. This work is an important step towards estimating the role of different phytoplankton groups in the global carbon cycle.



Size of algal cells regulates ecosystem processes: Primary production, CO₂ drawdown, length and complexity of food web, whole ecosystem production

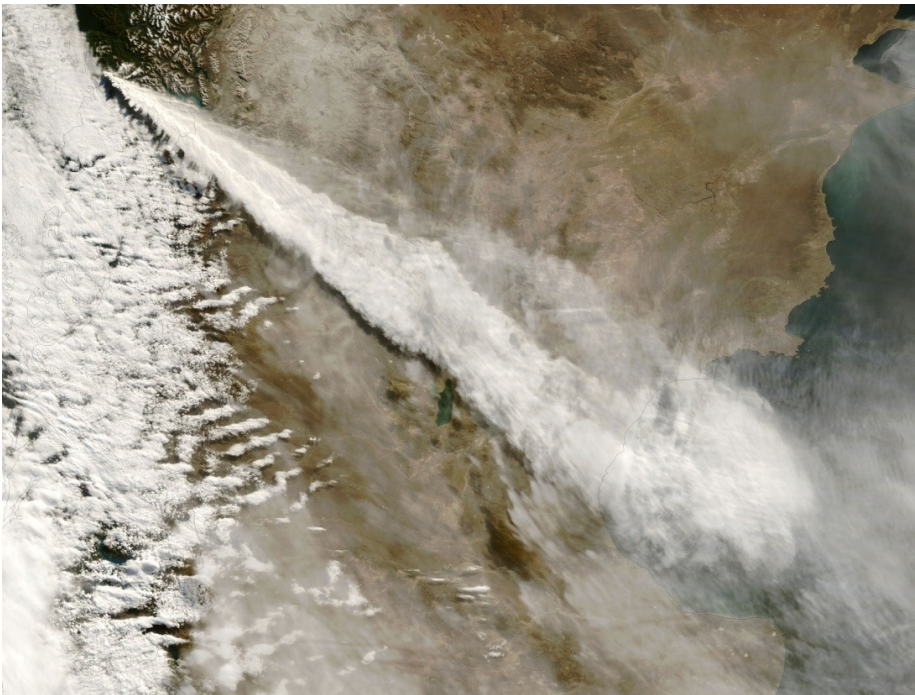
References

- Brewin R.J.W., S. Lavender, N.J. Hardman-Mountford, T. Hirata and R.M. Barciela. 2008. *An intercomparison of bio-optical techniques for detecting phytoplankton functional types from space*, Ocean Optics XIX, SPIE proceedings, PDF No. oo080577 (CDROM).
- Hirata T., J. Aiken, N.J. Hardman-Mountford, T. Smyth and R.G. Barlow. 2008. *Absorption model to determine phytoplankton size classes from satellite ocean colour*, Remote Sensing of the Environment. 112: 3153-3159.
- Hirata T., N.J. Hardman-Mountford, R.G. Barlow, T. Lamont, R.J.W. Brewin, T. Smyth and J. Aiken. In press. *An inherent optical property approach to the estimation of size-specific photosynthetic rates in eastern boundary upwelling zones from satellite ocean colour: an initial assessment*, Progress in Oceanography.

Rapid response to the Chaitén eruption provides once in a decade opportunity to refine models of ash dispersal

Sebastian Watt, David Pyle and Tamsin Mather,
University of Oxford

Within two days of the start of the Chaitén eruption it became clear that this was a major event - the largest volcanic eruption globally for nearly 20 years, and the largest explosive eruption of rhyolite for 90 years. We successfully applied for a NERC urgency grant in order to map out the distribution of ash from the eruption. Using MODIS satellite imagery to guide them, our field team mapped the ash fallout to a deposited thickness of ~ 0.1 mm, and collected samples from over 220 sites across an area of 100,000 square kilometers. With these field data and samples we were able to make the first scientific assessment of the size and impact of the eruption. Ash fallout on the ground corresponded closely to the areas identified on satellite imagery, allowing us to identify the time sequence of deposition of the different fallout units. Together with the grainsize and other data we have since collected, this will provide a once-in-a-decade opportunity to test and refine the current generation of models of ash dispersal and deposition. This will have a significant impact in terms of improving models of ash fall hazards from explosive eruptions. This work has so far yielded two papers (Watt et al., 2009; Martin et al., 2009), some press coverage (e.g. NERC's Planet Earth) and one scientific report (Carn et al., 2009). Our NERC Urgency Funding was eventually matched by support to international colleagues through both NSF and the University of Geneva.



May 3 2008 AVHRR image of Chaitén's plume on 3rd May 2008 stretching across Argentina towards the Atlantic coast

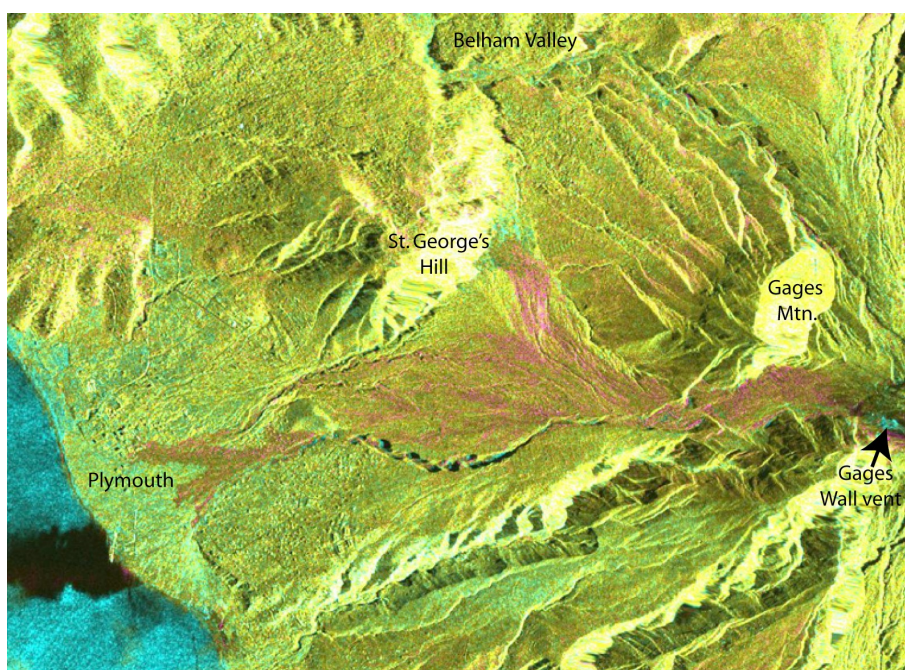
References

- Carn, S.A., J.S. Pallister, L. Lara, J.W. Ewert, S. Watt, A.J. Prata, R.J. Thomas and G. Villarosa, *The unexpected awakening of Chaitén volcano, Chile*, EOS, Trans. Amer. Geophys. Un., 90, 205-206, 2009.
- Martin, R.S., S.F.L. Watt, D.M. Pyle, T.A. Mather, N.E. Matthews, B. Georg, J.A. Day, T. Fairhead, M.L.I. Witt and B.M. Quayle, *Environmental effects of ashfall in Argentina from the 2008 Chaitén volcanic eruption*, J. Volcanol. Geotherm. Res., 184, 462-472, doi:10.1016/j.jvolgeores.2009.04.010, 2009
- Watt, S.F.L., D.M. Pyle, T.A. Mather, R.S. Martin and N.E. Matthews, *Fallout and distribution of volcanic ash over Argentina following the May 2008 explosive eruption of Chaitén, Chile*, J. Geophys. Res., 114, B04207, doi:10.1029/2008JB006219, 2009.

Activation of International Charter for the Soufriere Hills eruption means local people can return home safely

Geoff Wadge, University of Reading
working with British Geological Survey

From 27 to 28 July 2008, Soufriere Hills Volcano, Montserrat experienced an intense swarm of long-period seismicity that culminated in an explosion and eruptive column collapse. The resultant pyroclastic flows set buildings alight in the remnants of Plymouth, the largely destroyed former capital. Together with R. Stewart (Acting Director of the Montserrat Volcano Observatory), Professor Wadge activated the International Charter for Space and Major Disasters via the Cabinet Office on 29 July to obtain the most up-to-date remotely sensed data on the state of the volcano. The volcano was covered in cloud and so the effects of the explosion on the stability of the large lava dome could not be determined visually. By 1 August we had obtained high-resolution X-band radar images from the TerraSAR-X satellite that, together with earlier, equivalent data, were able to show the source and scale of the explosion's effects on the lava dome. The Montserrat government's civil protection committee were informed of this and were able to revoke the precautionary evacuation of people at risk from the dome on 6 August, a week or so before the dome was next seen by eye.



TerraSAR-X change difference radar image, showing the changes caused by the eruption of 28 July 2008. The small area of cyan colour is the Gages Wall vent of the volcano that was the source of the explosion. Pyroclastic flows of pumice flowed east and west from this vent and the magenta coloured area in this image shows the western flow which extended 4 kilometres into the abandoned former capital Plymouth. The still-populated area at risk from the eruption lies to the north in the Belham Valley.

References

Ager, G., Wadge, G., Tragheim, D., Jordan, C. (2008) *Volcanic eruption of 29th July 2008 on the island of Montserrat. Charter final operation report*. Charter for Space and Major Disasters, Charter ID:213, British Geological Survey Report no. CR/08/179, 48pp.

Continuous recording GPS measurements suggest large earthquakes probable along the Hellenic Arc

Philip England, Michael Floyd, and Barry Parsons, University of Oxford
James Jackson, University of Cambridge

Starting in 2003, COMET (Centre for the Observation and Modelling of Earthquakes and Tectonics), now the Dynamic Earth and Geohazards theme within NCEO, has with its partners, the National Technical University of Athens and the General Command of Mapping, Ankara, installed continuously recording GPS networks in southern Greece (16 sites) and western Turkey (11 sites). Three to five years of measurements are needed to achieve the required accuracy, and these networks are now starting to produce interesting results.



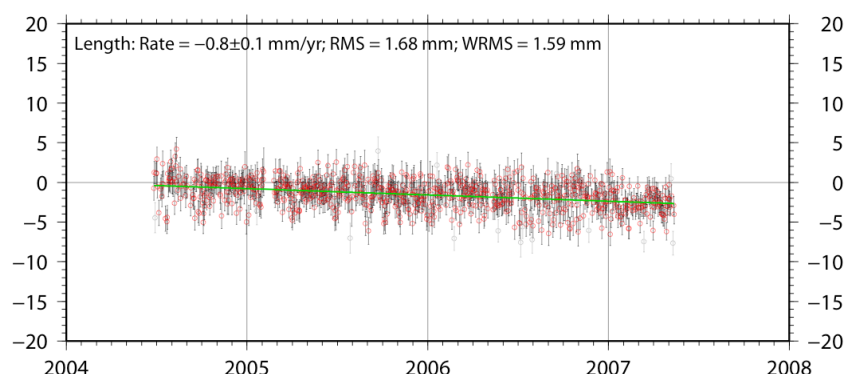
Locations of continuously recording GPS stations established by COMET and its partners in Greece (red circles) and western Turkey (blue circles).

Crustal strain and seismic hazard along the Hellenic arc

Measurements from the continuously recording GPS stations in Crete and southern Greece have been used together with a forensic investigation of the AD 365 earthquake in western Crete to estimate the likely repeat time of earthquakes producing tsunamis along the arc. Baselines that are approximately perpendicular to the Hellenic arc, and parallel to the azimuth of convergence across it, are contracting at a rate of about 1 mm/yr between southwest Crete and the volcanic arc. The contraction can be modelled as strain accumulation due to a slip deficit of about 3 mm/yr on the fault planes around southwest Crete, leading to an estimate of about 800 years for the repeat time between tsunamigenic earthquakes along the whole arc.

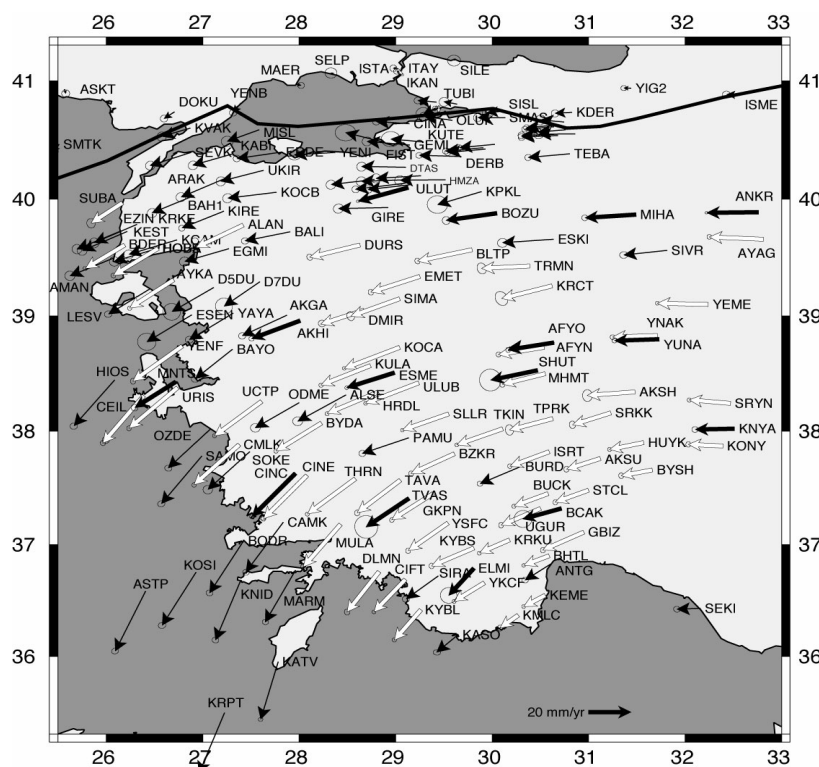
XRSO_SNTR

GPS measurements showing the slow decrease in the length of a line between a GPS station on western Crete and one on the volcanic island of Santorini behind the Hellenic arc



Analysis of rates of baseline length changes also provides the first geodetic measurement of extension parallel to the trend of the subduction zone, which previously has been studied geologically, at a strain rate of between 10-30 nanostrain/yr. A model for the long-term extension is formulated from the equations for a thin viscous sheet, which is used to allow the better estimation of recoverable interseismic strain accumulation in the presence of long-term extension. In this case, faults around south-west Crete are found to be accumulating slip deficit at a rate of between 10 mm/yr and 15 mm/yr, which is about 30-45% of the rate of convergence across the subduction zone. Potentially large earthquakes are not only possible but probable in the future along the Hellenic arc.

Testing models of crustal deformation in western Turkey with GPS measurements

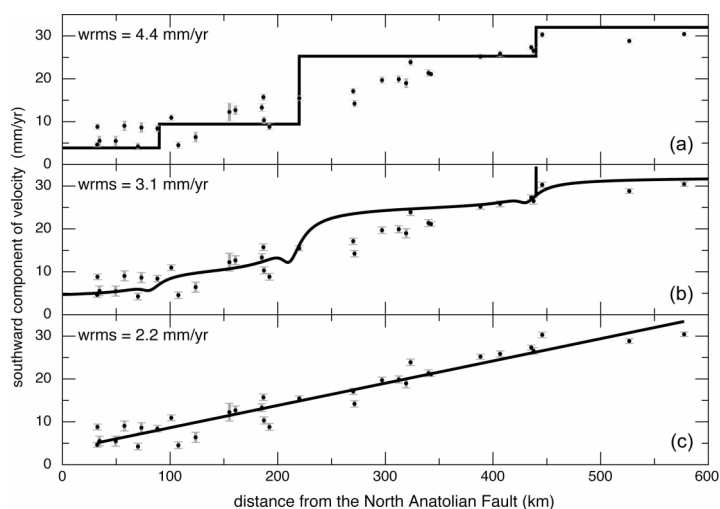


A new, detailed crustal velocity field for western Turkey determined from a combination of survey mode and continuously-recording GPS measurements

A paper to be published in submitted to the Journal of Geophysical Research (Aktug et al., 2009) presents the first results making use of the continuously recording GPS network installed in western Turkey in collaboration with our partners the General Command of Mapping. It describes a new geodetic velocity field covering western Turkey, south of the North Anatolian fault. Our velocity field is derived from a combination of continuously recording GPS stations operating since 2003, survey type GPS measurements carried out in the period 1997-2005, and previously determined velocities. The velocity field indicates that western Turkey currently undergoes extension whose rate increases from the Anatolia plateau to the Aegean coast. The overall extension in westernmost Turkey is about 20 mm/yr, one of the fastest areas of continental extension in the world. We tested whether the observed deformation is better represented by the rotation of crustal blocks or by more distributed deformation. While

no deformation is detected in the central Anatolian plateau, we observe a deformation field west of the plateau that cannot be explained by block models, unless the blocks are so small as to be essentially indistinguishable from a continuum. Although large strain rates (up to 140 nstrain/yr) are found across the major grabens, strain rates above 50 nstrain/yr are found throughout western Turkey. The distributions of topography and crustal thickness in western Turkey agree with the distributions expected if the crust there had a constant thickness at 5 Ma, equal to that of the present central Anatolian plateau, and had subsequently been thinned at the present-day distribution of strain rates. Our results, therefore, suggest that extensional strain affects the whole continental lithosphere of western Turkey, rather than being restricted to a small number of block boundaries.

Comparison of southward component of crustal velocities with predictions of different models along a north-south profile across western Turkey. Panel c shows that the observed velocities are best described by a uniform strain rate expected for continuum deformation rather than by two different block models shown in the upper two panels



References

Aktug, B., J. M. Nocquet, A. Cingöz, B. Parsons, Y. Erkan, P. England, O. Lenk, M. A. Gürdal, A. Kilicoglu, H. Akdeniz, and A. Tekgül, *Deformation of western Turkey from a combination of permanent and campaign GPS data: limits to block-like behaviour*, J. Geophys. Res., in press.

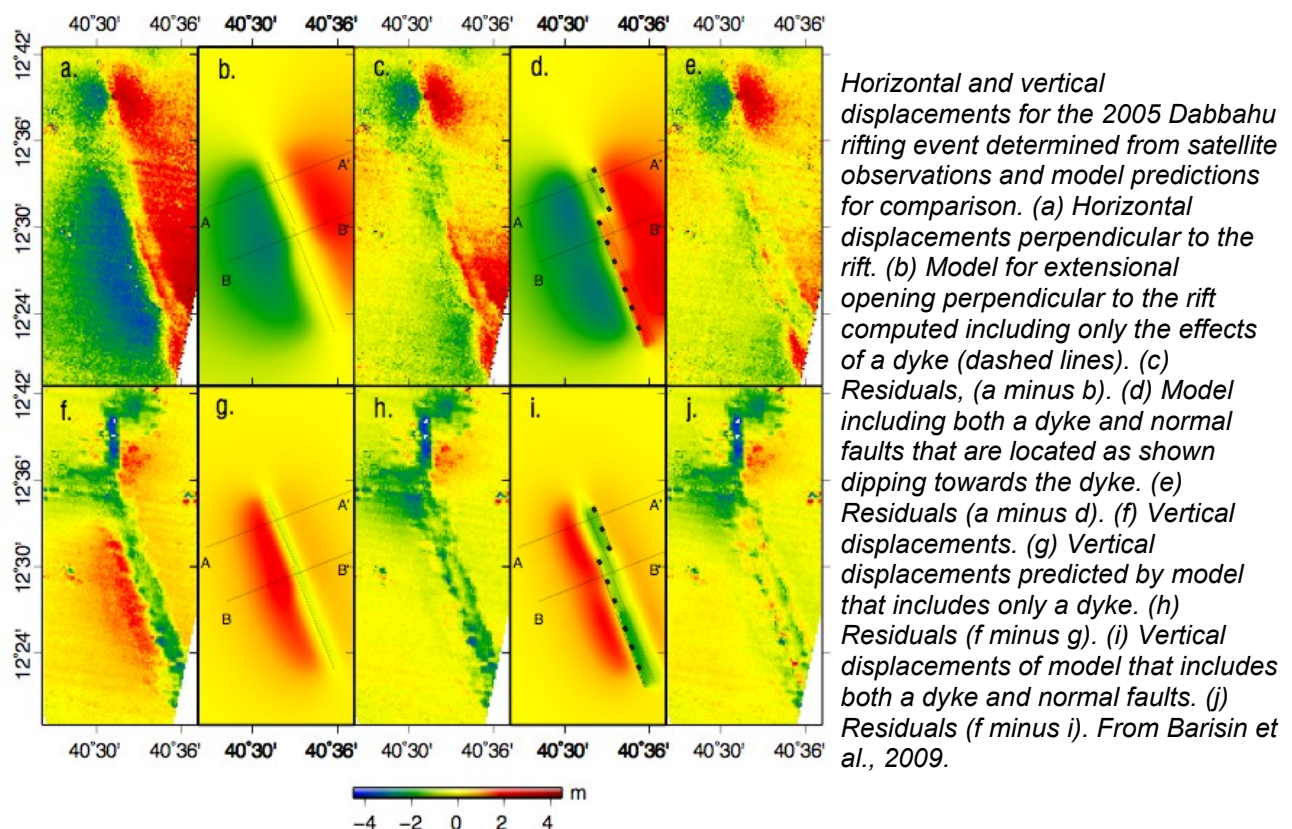
Monitoring the Afar rift valley, Ethiopia

Ivana Barisin and Barry Parsons, University of Oxford
Ian Hamling and Tim Wright, University of Leeds

COMET (Centre for the Observation and Modelling of Earthquakes, Volcanoes and Tectonics) is a partner in the Afar Consortium project. For the most part, we keep the achievements of the two groups separate. However, COMET and now NCEO fund the efforts of two PhD students who have been working on projects related to rifting in the Afar and report significant results this year.

Surface displacements in the September 2005 Afar rifting event from satellite image matching

Ivana Barisin, a NCEO-supported PGRA and part-time PhD student, has combined sub-pixel analysis of SPOT4 images with InSAR measurements to generate three-dimensional surface displacements for the September 2005 rifting event on the Dabbahu Segment in the Afar valley. The axis of rifting in the event is found to be shifted to the east of the geomorphic rift and vertical displacements show asymmetric uplift of the flanks of the dyke. Simple forward modelling indicates this asymmetry is due to the dyke dipping 80 degrees to the west towards the geomorphic rift. The boundary between eastward and westward displacements aligns with the transition between uplift and subsidence on the east in the north part of the segment, but on the west in the south. Normal faulting is not required on both sides of the instantaneous rift. East-dipping normal faulting on the west side of the instantaneous rift aligns with a west-dipping normal fault in the topography.

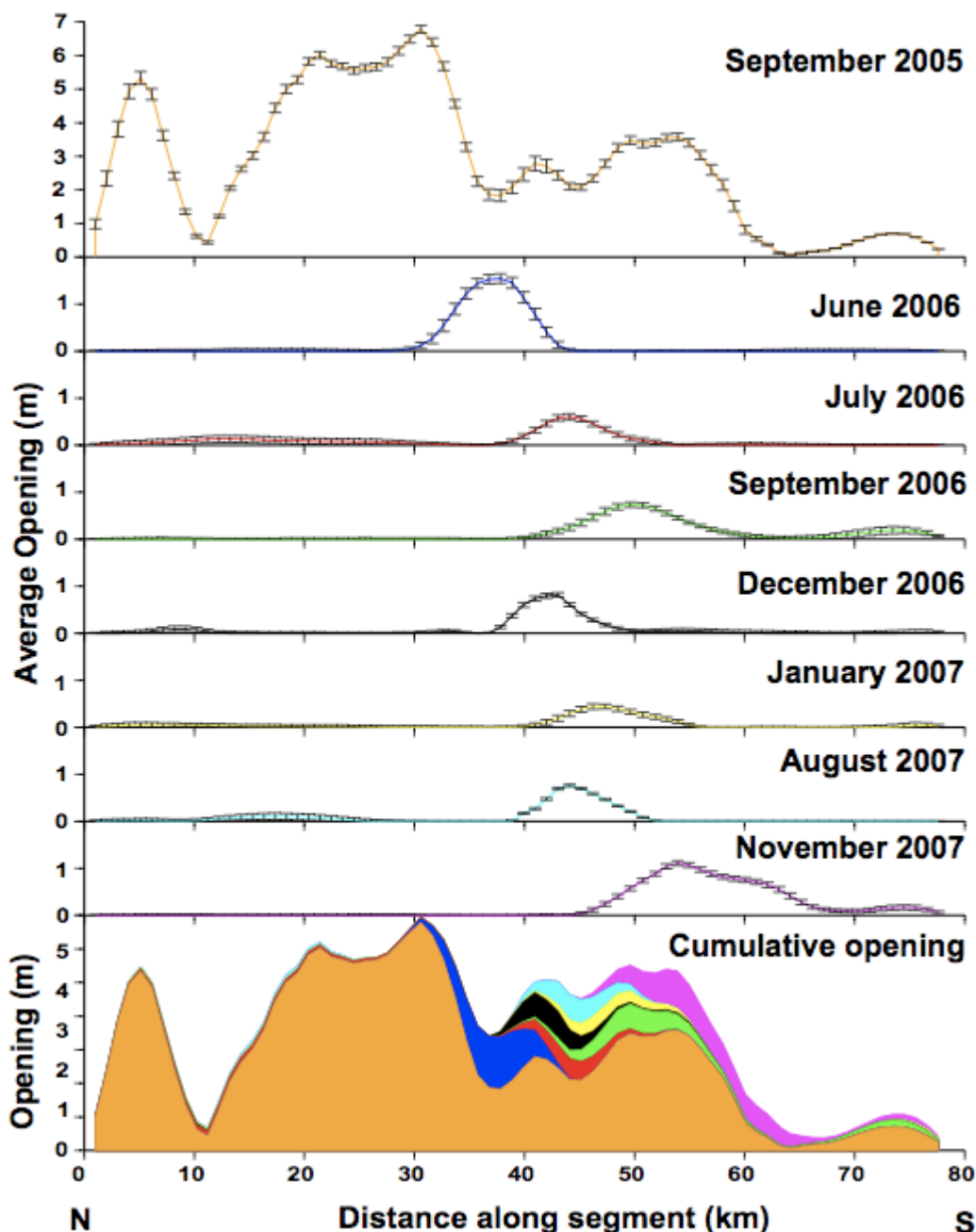


References

Barisin, I., S. Leprince, B. Parsons, and T. Wright, *Surface displacements in the September 2005 Afar rifting event from satellite image matching: asymmetric uplift and faulting*, *Geophys. Res. Lett.*, 36, L07301, doi:10.1029/2008GL036431, 2009

Ongoing monitoring of dyking in Afar

Ian Hamling, a COMET-supported PhD student, has continued to monitor ongoing activity in the Dabbahu segment of the Afar rift, Ethiopia. There have now been 11 new dyke intrusions since the large dyke of September 2005. InSAR data continue to show very rapid movements, making this one of the most rapidly deforming places on the planet at present. Ian's analysis of the dyke intrusions suggests that new intrusions respond to the stress changes caused by the most recent dyke, rather than the cumulative tectonic stress pattern from many dykes. Hazard results are being reported to the Afar government.



Vertically averaged opening for dykes intruded in the Dabbahu segment of the Afar rift between 2005 and 2007. The cumulative opening (bottom) suggests that new dykes are intruded where opening was least in 2005. From Hamling et al, 2009.

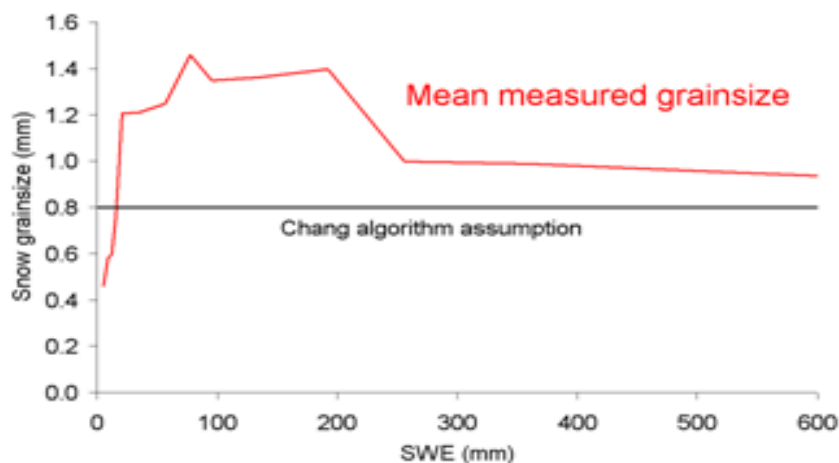
References

Hamling, I. J., A. Ayele, L. Bennati, E. Calais, C. J. Ebinger, D. Keir, E. Lewi, T. J. Wright and G. Yirgu, *Geodetic observations of the ongoing Dabbahu rifting episode: new dyke intrusions in 2006 and 2007*, *Geophys. J. Int.* 178, 989–1003, doi: 10.1111/j.1365-246X.2009.04163.x, 2009

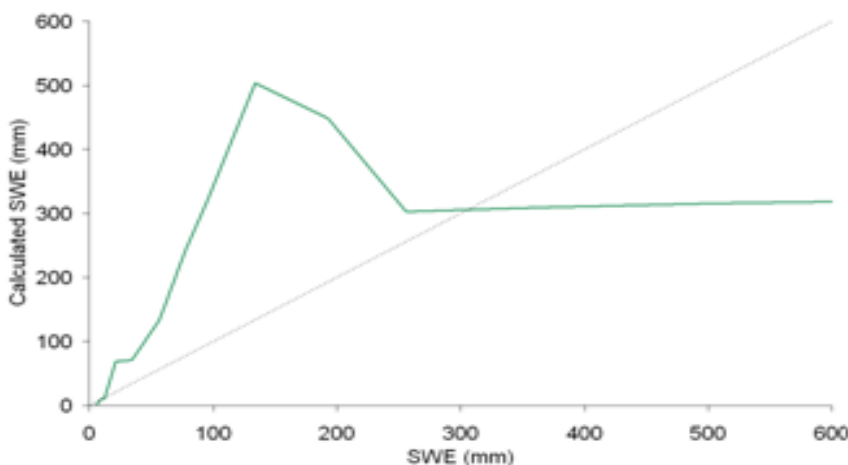
Improved estimates and representation of global snow mass

Mel Sandells, Ian Davenport, Robert Gurney and Debbie Clifford,
University of Reading

Snow is important as a source of water for agriculture, drinking and power generation for large parts of the world. Global monitoring of snow mass from remote sensing carried out by satellites is a vital tool in water resource management, environmental risk assessment and studying the sensitivity of climate to change. We have shown that the technique used for retrievals of global snow mass from passive microwave data for the past thirty years depend strongly on the snow structure, and can give very misleading results. The origins of the current widely-used technique were investigated, and extensive field campaign measurements, modelling and analysis used to characterise its shortcomings when faced with the range of snow properties typically found in a snowpack. These conclusions were presented and discussed at a special American Geophysical Union session in San Francisco. There was general agreement with the conclusions and the need for improvements in the technique that a cross-disciplinary group such as NCEO is well-placed to pursue. An NCEO researcher has just spent three weeks at the United States Department of Agriculture at their invitation testing a new snow Soil-Vegetation-Atmosphere Transfer (SVAT) model to assimilate microwave observations, and we are currently developing the physical models and assimilation techniques for a broader range of observations to improve remotely-sensed snow mass retrieval. Refereed papers are currently being written and reviewed.



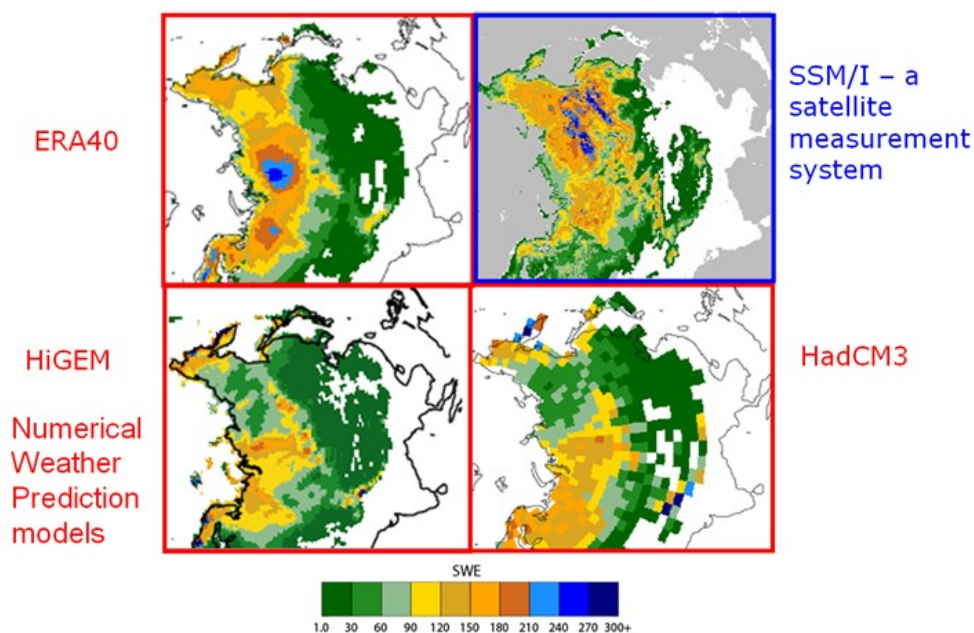
The effect of variability in grainsize on snow mass (SWE) retrieval. The left figure shows mean measured grain diameter over a range of snow mass over a large field site; the current Chang algorithm assumes a fixed value of 0.8mm. The right figure shows how this variability affects snow mass calculated from the existing model as a function of the actual snow mass.





Fieldwork to measure snow physical properties in Boise, Idaho

The way snow on the land surface is represented in both weather and climate models have been examined and compared against observations. It appears that the models precipitate much further west in Siberia than is seen from the satellite, and also are more zonal. Model resolution does not appear to affect the results. There appears to be a clear ENSO signal in both North America and Eurasia, with predictability a season ahead, which could have economic value. Journal papers are forthcoming, and this work also won a best student paper award at the AGU Fall Meeting.



Siberian mean snow mass distribution in February, calculated using model predictions (red) and satellite measurements (blue).

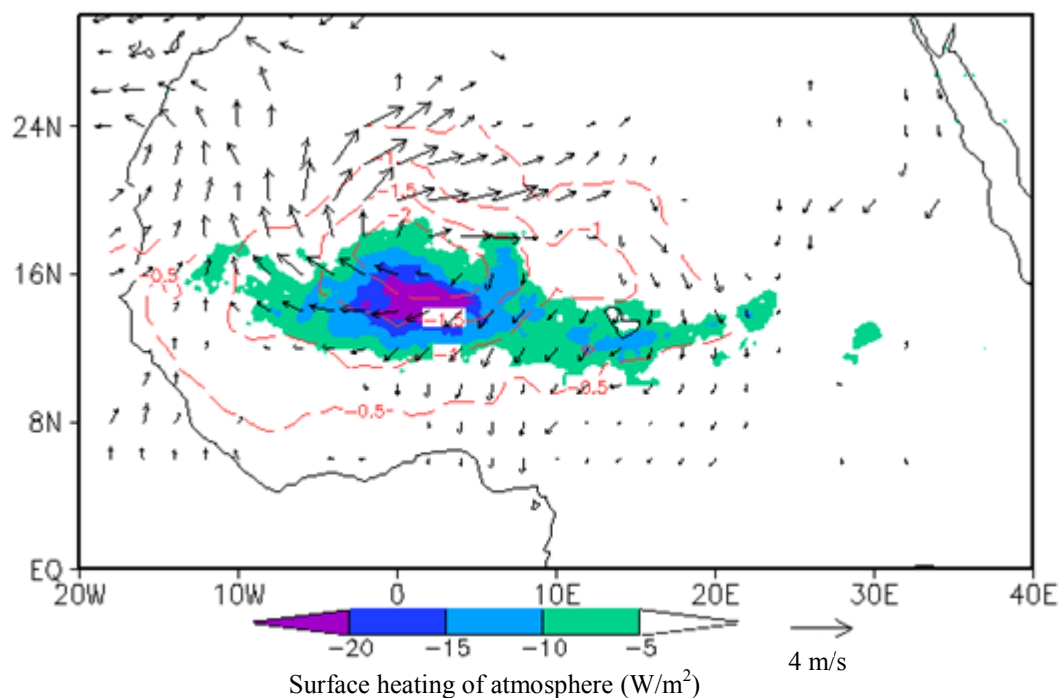
References

- M. J. Sandells, I. J. Davenport, D. J. Putt and R. J. Gurney, *Accuracy and sensitivity of snow water equivalent retrieval from the Chang algorithm*, under review.
- I. J. Davenport, M. J. Sandells, D. J. Putt and R. J. Gurney, *The effects of variation in snow properties on snow mass estimation using the Chang algorithm*, in preparation.
- D.J. Putt, R.J. Gurney and K. Haines, *Effect of ENSO phase on large scale snow water equivalent distribution in a GCM*, accepted for publication in J. Climate.

Potential for improved rainfall forecasts for the African monsoon

Chris Taylor, Centre for Ecology and Hydrology

This research demonstrated how feedbacks between rainfall and soil moisture influence the evolution of the rainy season in West Africa. It has been known for some years that there are periods (typically lasting a week) of more intense storms across the region followed by drier spells. We used satellite data to show how the resulting pulses of soil moisture fed back on the atmosphere. Drier soils warm the overlying air and strengthen the winds which bring humidity over the continent and lead to rain. This is the first time that observations have been used to quantify this feedback process. The fluctuations in rain within a season are critical for African agriculture, and application of the results of this study should lead to improved rainfall forecasts.



The figure illustrates the effects of wetter soil (shading) on monsoon winds. Wet soils reduce temperatures in the lower atmosphere (red lines K) via weakened surface heating. This creates a vortex, with stronger monsoon winds near the west coast and enhanced winds from the Sahara bringing dry air over the Lake Chad region to the east.

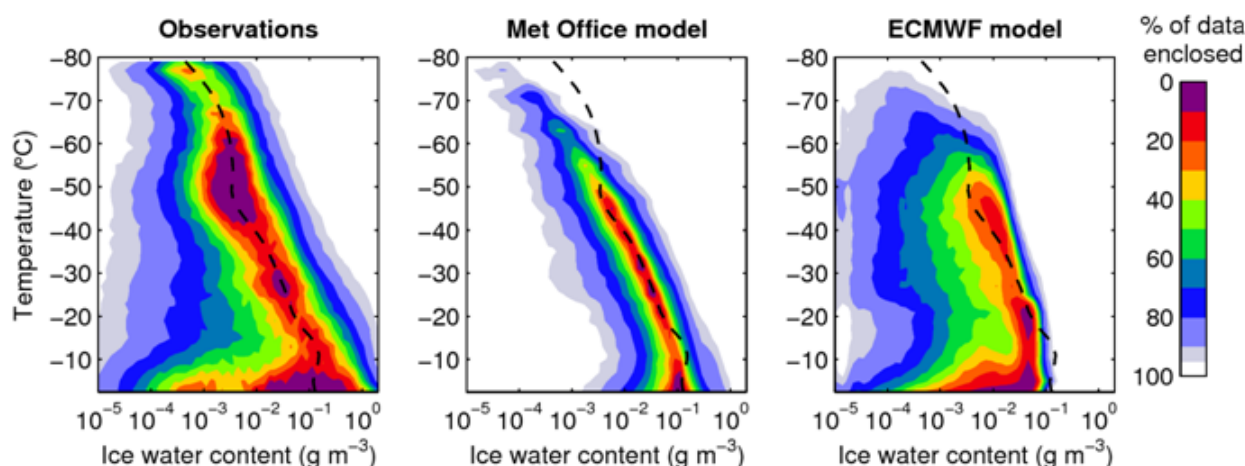
References

Taylor, C. M., *Intraseasonal land-atmosphere coupling in the West African monsoon*, 2008, J. Climate, 21: 6636-6648

Satellite data provides new insight into model ice cloud distributions

Robin Hogan, Julien Delanoë, University of Reading

Ice clouds play a key role in the climate system via their interaction with solar and infrared radiation and their importance for precipitation formation. Our retrievals of cloud "ice water content" from the spaceborne CloudSat radar and CALIPSO lidar have been used to test the values held in the global forecast models of the Met Office and the European Centre for Medium-Range Weather Forecasts (ECMWF). We have found that the Met Office gets the average approximately right for a given temperature, but drastically underestimates the spread, while ECMWF has an unphysical "cut-off" value of ice water content, above which ice clouds are converted to snow and fall out instantaneously. Both models underestimate the occurrence and water content of cirrus clouds colder than -60°C . Our findings highlight oversimplifications in the way cirrus clouds, mid-latitude frontal clouds and deep convection are being represented, which has not been revealed until now. These results are currently being used at ECMWF in the development of the new cloud scheme in their model.



Global distribution of ice water content versus temperature for CloudSat-CALIPSO retrievals and two forecast models, for the month of July 2006. The dashed black line shows the location of the peak in the observed distribution, to aid comparison between the three different distributions.

References

Delanoë, J., and R. J. Hogan, 2008: *A variational scheme for retrieving ice cloud properties from combined radar, lidar, and infrared radiometer*, J. Geophys. Res., 113, D07204, doi:10.1029/2007JD009000.

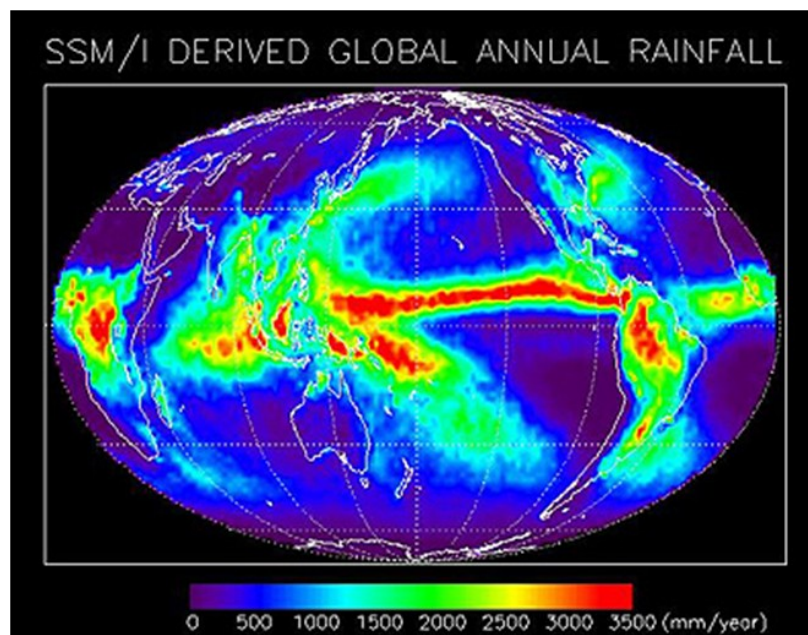
Delanoë, J., and R. J. Hogan (2008), *Combined CloudSat-CALIPSO-MODIS retrievals of the properties of ice clouds*. J. Geophys. Res., submitted.

Improved understanding of how rainfall responds to a warming world

Richard Allan, University of Reading



Through collaboration with the University of Miami, an intensification of rainfall extremes during warmer months was identified for the first time using daily satellite measurements and compared with state-of-the-art climate model simulations. Qualitative agreement was found, corroborating the simulations, yet detailed analysis suggested that the observed amplification of rainfall extremes was larger than predicted by the climate prediction models with important implications for projected future changes in the global water cycle but also for the integrity of the satellite observing systems. The work was published in the journal, *Science*, and covered by world media.



Comparing observations with results from computer models improves understanding of how rainfall responds to a warming world. Differences can relate to deficiencies in the measurements, or the models used to predict future climatic change.

References

Allan, R. P. and B. J. Soden (2008), *Atmospheric Warming and the Amplification of Precipitation Extremes*, *Science*, 321, (5895) p.1481-1484

Allan, R. P. and B. J. Soden (2007), *Large discrepancy between observed and simulated precipitation trends in the ascending and descending branches of the tropical circulation*, *Geophysical Research Letters*, 34, L18705, doi:10.1029/2007GL031460

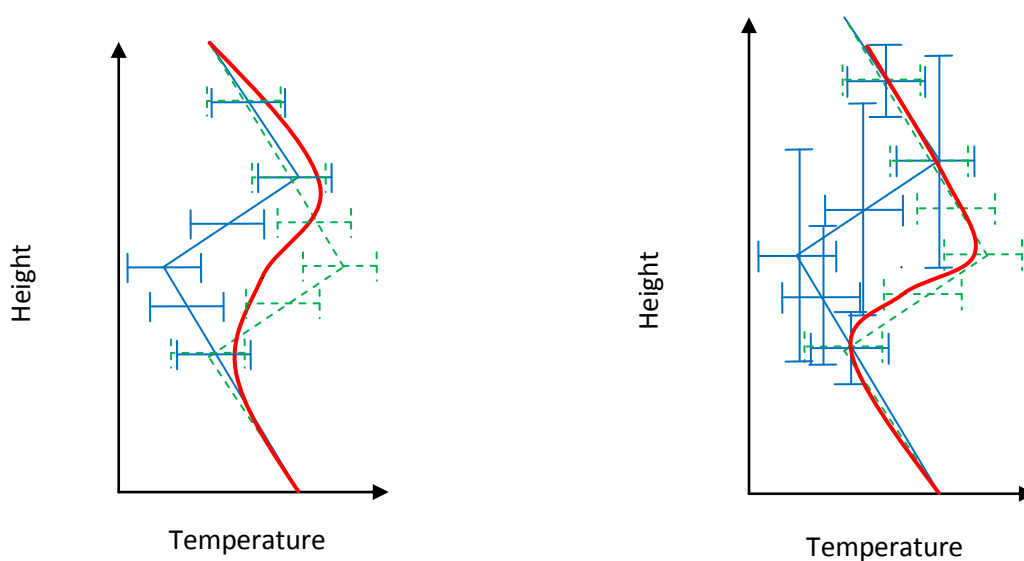
John, V.O., R.P. Allan and B.J. Soden (2009), *How robust are observed and simulated precipitation responses to tropical ocean warming?* *Geophysical Research Letters*, 36, doi:10.1029/2009GL038276

Assimilation of coherent structures

Alison Fowler, Ross Banister, Stefano Migliorini, Alan O'Neill,
Peter Jan van Leeuwen, University of Reading
John Eyre, Met Office

Data assimilation is a method to combine numerical models with observations. It is used in all environmental sciences and essential to be able to simulate the real world, instead of a pure model world that has little to do with reality. With the ever-increasing complexity of the geophysical models and observations a completely new area in (and era for) data assimilation with several new challenging problems has been opened.

One of these problems is that the model simulates a coherent feature, like a convective event with high rainfall, with the correct structure but in the wrong position. Standard data-assimilation schemes will try to pull the feature to the correct place, destroying its coherent structure. A new data-assimilation scheme has been developed that adds positional errors to the forecast error covariance. The procedure is illustrated here on the height of the boundary layer, which is important for the formation of clouds.



Amplitude errors of temperature are given for the *forecast* and *observations*. In the figure on the left no consistent *analysis* can be found due to the large disagreement in the position of the inversion. Instead the *analysis* produced loses the inversion structure that was consistently seen in both the *forecast* and *observations*. In the figure on the right vertical positional errors are included in the *forecast* fields. Now the *forecast* and *observed* temperature profiles are more consistent and an *analysis* is found which keeps the inversion structure.

Curating and providing access to EO data

Victoria Bennett and CEDA staff, Rutherford Appleton Laboratory

CEDA, the Centre for Environmental Data Archival, which includes the British Atmospheric Data Centre (BADC) and the NERC Earth Observation Data Centre (NEODC), is responsible both for curating data generated by NERC funded activities and for facilitating the access to data required by NERC science. During 08/09 the CEDA Data Centres:

- handled 3822 user queries through “helpdesks”,
- gained almost 2000 new registrations, giving a total of over 12,000 registered users,
- provided 48 TB of data (36TB BADC, 12TB NEODC) , in 12 million files to users,
- held 256 TB of data as primary copy in the archives.

Example dataset: NERC Airborne Research and Survey Facility (ARSF)

NEODC archives and makes available over 25 years' of NERC ARSF data, including aerial photographs, multispectral imagery and LiDAR data. The data are currently processed by ARSF-DAN, the ARSF Data Analysis Node at PML Plymouth, from where they are transferred to NEODC for long-term archival and dissemination. This year has seen a significant increase in data volumes routinely acquired and archived, with the introduction of the new Specim Eagle and Hawk hyperspectral instruments.

ARSF data is the NEODC's most popular dataset, with 41 users downloading digitised aerial photographs (90GB), and 50 users downloading over 200GB of other types of data from the other ARSF instruments (e.g. hyperspectral data from Eagle and Hawk).



One activity this year involved the “rescue” of old ARSF data previously held elsewhere. NEODC collected approximately 25 boxes containing 1500 CDs, 700 DAT tapes, and 600 Exabyte tapes. This included raw and processed data, calibration and navigation data and miscellaneous back-ups. These items filled a number of gaps in the NEODC archive and all the data which can be recovered has now been ingested and catalogued. (Not all the data was recoverable, for a variety of reasons, not least, inadequate metadata describing exactly what was measured, where, and how.)

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